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ABSTRACT

Background information, lists of materials needed and procedures used are provided for 16 simple experiments on electricity and magnetism. These experiments are organized into sections dealing with: (1) Edison's carbon experiments (building a galvanometer, investigating the variable conductivity of carbon, and examining the carbon transmitter principle); (2) a model telephone transmitter (building and testing the transmitter); (3) magnetism (making a magnet and identifyng the poles, making an electromagnet, investigating magnetism and the compass, and making an electromagnet with two coils); (4) Edison's home lighting circuit (investigating series circuits, parallel circuits, and fuses); and (5) Faraday experiments (building an electrophorous, building an electroscope, conducting Faraday's "ice pail experiment," determining if ice conducts electricity, and electroplating a house key). Diagrams illustrating procedures and/or equipment are included when applicable. (JN)

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OF THOMAS ALVA EDISON

He has led no armies into battle . . . he has conquered no countries . . . yet he wields a power the magnitude of which no warrior ever dreamed . . . this democratic, kindly, modest man has bestowed upon the human race blessings instead of bondage, service instead of serfdom, construction instead of conquest . . . he is humanity's friend.

Arthur J. Palmer

Simple Experiments on Magnetism and Electricity . . . from Edison

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TO THE YOUNG PEOPLE OF AMERICA

Thomas Edison worked hard at experimenting. To him, it was a way of life . . . the most positive way of testing the ideas that occurred to him constantly.

This booklet, based largely on Edison's work, is designed to give you some idea of the experiments Edison performed to achieve a few of his many inventions and developments.

We hope that by following Edison's methods of invention, you will learn the crucial importance of thorough experimental work. We also hope that doing these simple investigations will be pleasant, so that you will know some of the satisfaction scientists find in their work.

Today our country, as well as the entire world, needs young men and women with the kind of imagination, courage, and willingness to work hard that enabled Edison to conquer so many difficult problems.

If your interests lead you to one of the scientific or technical fields, you will have not only the excitement and challenge of a demanding career but the realization that you are helping your country at a time when you are greatly needed.

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EXPERIMENTS

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EDISON'S CARBON EXPERIMENTS

Most people think of Thomas Edison as an inventor of mechanical and electrical devices. But he was more than an inventor. He was a discoverer as well. And many of his great contributions were not devices; they were observations . . . observations that blossomed because of his keen mind and curiosity about the unusual.

One unusual thing that particularly interested Edison was the way pressure affected the electrical resistance of a mass of carbon particles. Like others before him, Edison noticed that when current flowed through such a mass, applied pressure allowed more current to flow. And when the pressure was removed, the flow decreased. As we shall see, this observation later led to Edison's development of the telephone transmitter.

Edison first observed the variable resistance, or variable conductivity, of carbon in 1873. He pressed graphite, a form of carbon, in glass tubes and inserted wires in the graphite at both ends. And he found that the slightest pressure on the end of the tubes changed the resistance.

Four years later he successfully exploited this curious property of carbon in inventing the carbon transmitter, or microphone. In his attempts to make the transmitted voice sounds as clear as possible, Edison tried various forms of carbon, including graphite sticks and "carbon buttons" (made by pressing soot from kerosene lamps into little cakes). He even experimented with materials other than carbon.

Some of the experiments that follow will enable you to check carbon's conductivity properties for yourself. They may also give you some idea of how Edison carried out his endless search for the solution to whatever problem he tackled.

For these experiments you will need a sensitive instrument to detect small current flows. Such an instrument is called a galvanometer. It not only indicates the presence of current, but it also shows when the flow reverses direction.

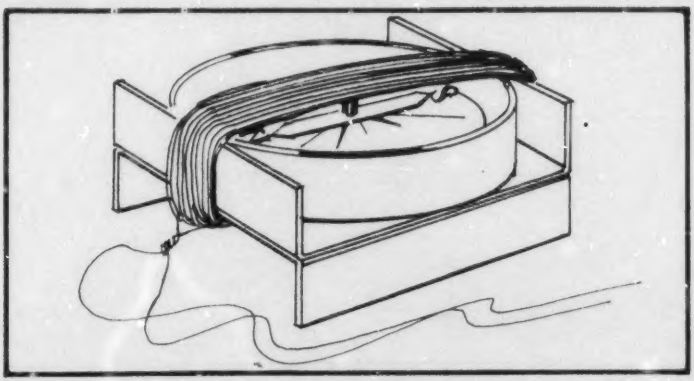
EXPERIMENT 1

Building a Galvanometer

THINGS YOU NEED. A compass. Small spool of magnet wire (#28 or finer). Piece of thin, stiff cardboard.

Cut the cardboard as wide as the compass but long enough to fold up at the ends (see drawing). Then cut and fold another piece the same as the first. Glue the two cardboard pieces back to back to form a cradle, as shown.

Place the compass inside the cradle so that the N-S axis points toward the closed sides. Finally, wind about 100 turns of wire around the compass and cradle right over the N-S axis. Twist the free ends a few times to keep the coil from unwinding.



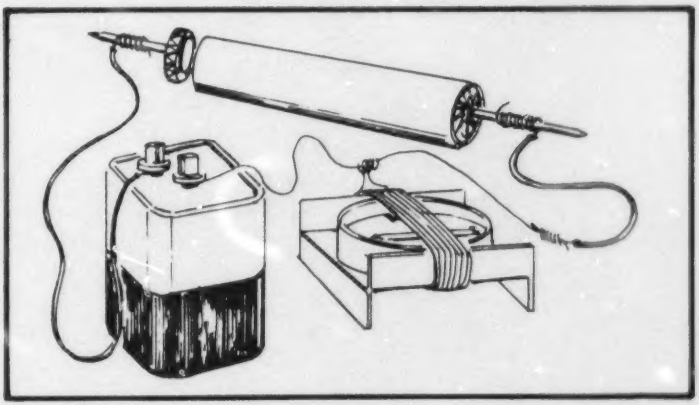
Trim both ends of the coil to about 12". Then scrape 1/2" of enamel insulation off the wire tips. And that's it. That's our galvanometer.

Here's how it works: Whenever current flows through the coil, it creates a magnetic field around the coil. With the coil and needle aligned in the N-S direction, the field tends to swing the needle toward the E-W direction. You can tell how strong the current is by how much the needle swings. And you can tell that current is flowing in the opposite direction when the needle points to the other side.

EXPERIMENT 2

The Variable Conductivity of Carbon

THINGS YOU NEED. Tube of powdered graphite (most hardware stores carry plastic squeeze tubes of graphite lubricant; but make sure it's graphite, not something else). Small non-metallic tube. 2 nails with wide heads (roofing nails). Paper napkin. 2 or 3' of hook-up wire. 6-volt battery. Galvanometer from Experiment 1.



First cut two pieces of wire about 12" long, and remove 1" of insulation from the ends. Take one of the wires and wrap a bared end around the shaft of one of the nails. Do the same with the other wire and nail. Try to make the connections tight, and use tape to keep them in place. Better yet, solder the connections if you can.

Next wrap napkin strips around the nail shafts, enough so that each nail fits snugly (head first) into the non-metallic tube. With a nail inserted in one end of the tube, fill the tube with graphite. Leave room for the second nail; then close the tube with that nail.

Now connect the tube wires to the galvanometer and battery, as shown. Note that when the circuit connections are completed, current begins flowing, as indicated by the compass needle. If the needle doesn't move, check all connections. You may have to scrape some of the surfaces clean to make good contact. See what happens when you push the nails deeper into the graphite. Also, tap on one of the nails to make it vibrate, and observe the reading.

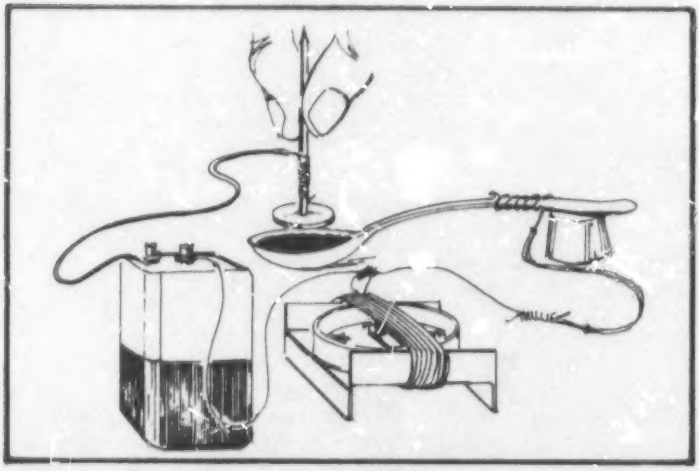
This experiment shows what Edison learned about carbon particles: A mass of such particles is electrically sensitive to movement, and so its conductivity is affected by pressure.

EXPERIMENT 3

The Carbon Transmitter Principle

THINGS YOU NEED. Graphite, nail, wire, battery, and galvanometer from Experiment 2. Tablespoon. A penny.

Remove the tube from the circuit, and take a nail off one of the wires (leave the other nail on). Tie the end of the free wire around the spoon handle; secure it with tape.



Prop something under the spoon handle to make the container level. Fill the container with graphite and tap the graphite gently with a flat stick.

While watching the galvanometer, lightly touch the nail to the graphite. Touch several areas, varying the downward force. The compass needle should move each time, but not to the same degree.

Now place the penny on the graphite. Make sure that the coin does not contact the spoon. With the nail, touch the penny lightly. Note how much the galvanometer needle swings. Then press down on the penny with the nail. Again check the galvanometer. The needle should have swung further, indicating that more current flowed.

With this experiment, you have demonstrated the basic principle used by Edison in his carbon transmitter. It is the same principle used in the mouthpiece of our telephones today. Pressure waves caused by your voice act on a diaphragm in the telephone (just as the pressure from the nail acted on the penny). The resulting vibrations vary the current passing through the carbon. These electrical variations correspond to the sound waves of your voice.

A MODEL TELEPHONE TRANSMITTER

Many of Edison's exploits consisted in devising something never before attempted or even thought of. However he also made some important contributions by improving the inventions of other people, which helped make those inventions practical and widely useful. Take the telephone, for example.

Alexander Graham Bell was the first person to transmit speech over an electrical circuit. In Bell's original telephone, voice sounds directed into a speaker caused a diaphragm to vibrate. The vibrations of the diaphragm then induced weak electric impulses in a magnetic coil. The impulses traveled to the other end of the telephone line. There they produced similar vibrations in another diaphragm and were changed back to sound waves.

But the electric impulses were weak. Consequently, the speech carried only faintly and was difficult to hear and understand. Furthermore, the weak impulses limited Bell's range to only a few miles at best.

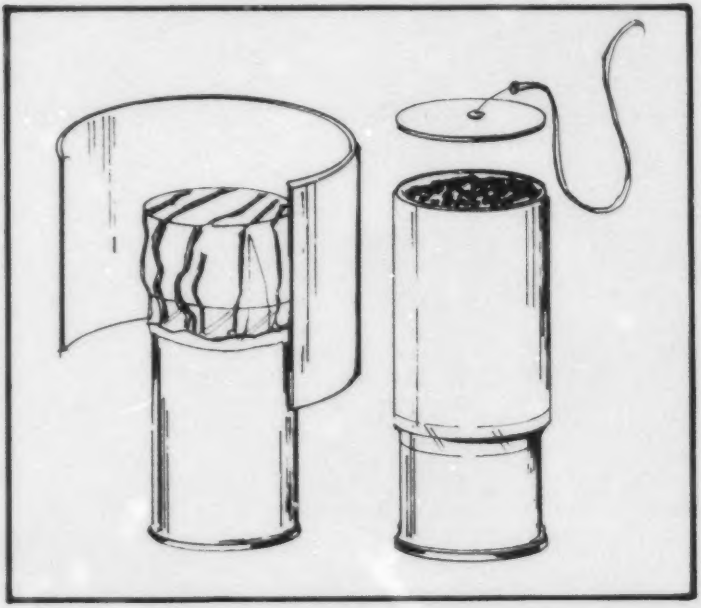
Edison helped make Bell's telephone a practical success by introducing the carbon transmitter. With his transmitter, Edison did not have to depend on the voice alone for the strength of the electric impulses. He used a carbon button to vary the flow of current from a storage battery. The current flowed from the battery to the carbon button in the transmitter, through an induction coil, and then back to the battery. The induction coil boosted the voltage of the impulses produced by the voice vibrations.

These reinforced impulses were then put on the main line where they could travel great distances yet still be heard clearly. Edison gave credit to his deafness for the improvements he made in the telephone. He said, "I *had* to improve the transmitter so I could hear it."

EXPERIMENT 4
Building a Carbon Transmitter

THINGS YOU NEED. An all-metal frozen-juice can (or can of similar size). Aluminum foil. Thin cardboard. Tape. 1' of hook-up wire. Graphite from Experiment 2 (carbon granules, such as used in refrigerator deodorizers, would be even better). Sandpaper.

First we'll have to make a mouthpiece to talk into. The frozen-juice can will serve that purpose. Remove the top and bottom of the can with a rotary opener, to keep the edges smooth. Save one of the lids. Cut a circle of aluminum foil an inch larger than the can opening, and fasten the foil tightly over the can with tape. This will be our diaphragm.



Next, with sandpaper, clean the entire surface of one side of the lid until bare metal shows. Then sand a small spot on the other side of the lid. Solder the bared end of 1' of hook-up wire to that spot. If you don't have soldering equipment, use tape.

To hold the carbon, wrap a sheet of cardboard around the end of the can having the diaphragm. With about 1/2" or less of cardboard extending above the diaphragm, tape the cardboard to the can. Make sure the overlapping edge of the cardboard is taped too, so the carbon can't spill out.

Fill the entire volume between the diaphragm and the top of the cardboard with carbon. Better spread out some newspaper to avoid a mess. To complete the transmitter, place the lid on the carbon so that the sanded side touches the carbon. Now tape the lid snugly in place against the carbon.

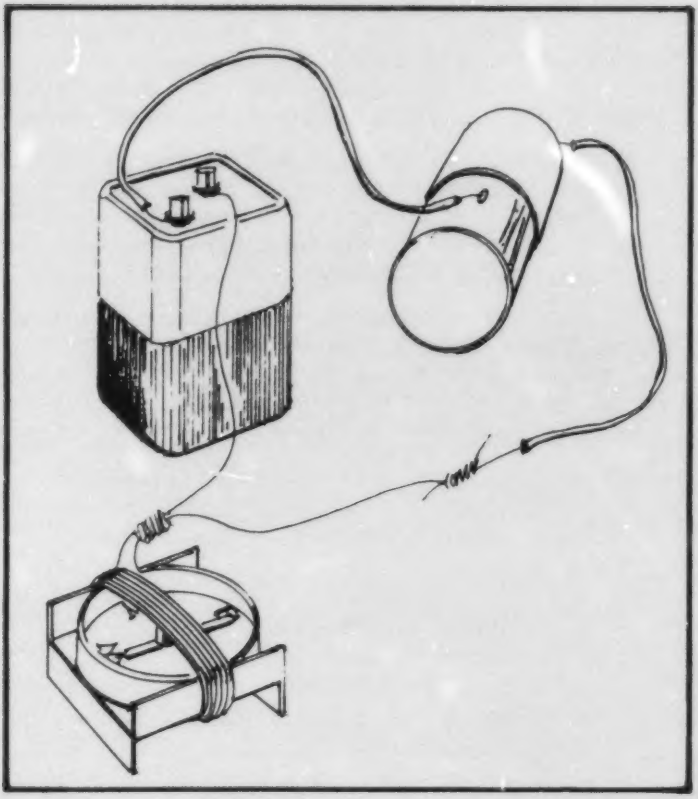
EXPERIMENT 5

Testing the Transmitter

THINGS YOU NEED. Transmitter from Experiment 4. 1' of hook-up wire. Galvanometer from Experiment 1. 6-volt battery.

Connect the circuit as shown in the diagram. Before soldering (or taping) the wire to the side of the can, scrape that spot on the can down to the bare metal. Good connections are important. It is also important that the compass needle point to N at the start. When the connections are completed, the needle should move away from N and stay there. If it doesn't, check the connections and shake or tap the can a couple of times.

Once the needle moves, we can begin the test. Make any kind of *loud* noise into the open end of the can, and watch the needle.



It should move back and forth. That's because the sound waves from your voice vibrate the diaphragm and cause a varying pressure on the carbon. And as you learned in Experiments 2 and 3, varying pressure on carbon varies its electrical resistance, which changes the current flow. If you're not getting results, check the lid. Maybe it isn't pressing against the carbon tightly enough.

This experiment illustrates, once again, the principle of Edison's carbon transmitter, which made possible long-distance telephone usage.

MAGNETISM EXPERIMENTS — THE TELEGRAPH

Originally the telegraph was a simple system for sending messages along a wire by means of electric impulses. For more than 40 years in the mid-1800s it served as man's fastest means of long distance communication. It was the reason the famous Pony Express ended.

When young Edison became interested in the telegraph, it could transmit only one message at a time on any one wire. And since the telegraph had been playing such a vital role in our country's economic growth, the system couldn't keep up with the flood of messages pouring in. Edison wanted to develop a system that could carry more than one message at the same time.

He began studying all that he could on the subject. He experimented endlessly. As a result he not only made major improvements to the existing duplex, which handled two messages simultaneously; but he invented the quadruplex, which handled four. Modern telegraph systems, of course, go far beyond this capability. But for that period, 1874, four messages at once was quite an accomplishment.

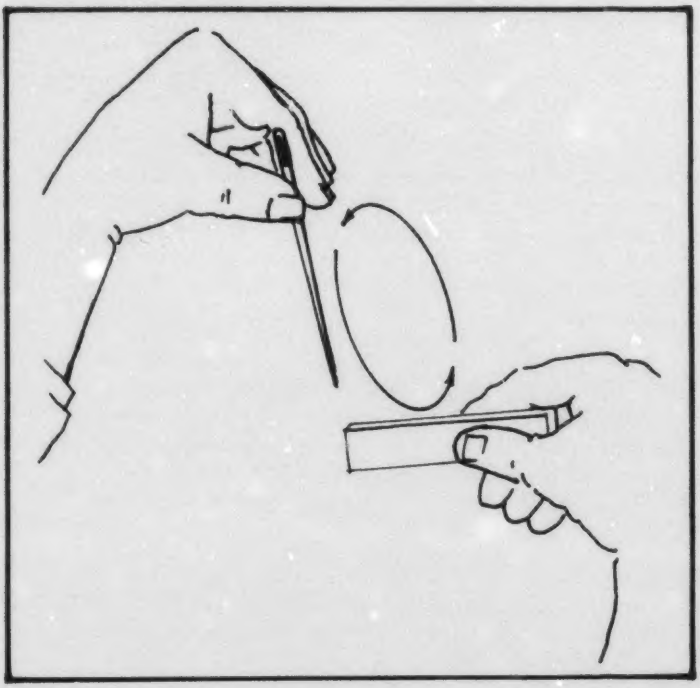
Several experiments follow that illustrate some of the fundamental principles upon which Edison based his telegraph inventions. They involve the inseparable relationship between electricity and magnetism.

EXPERIMENT 6

Making a Magnet and Identifying the Poles

THINGS YOU NEED. Bar magnet. Large sewing needle. Iron filings or crumbled steel wool.

Hold the sewing needle at the eye, and stroke it repeatedly toward the point with the bar magnet. Always stroke in the same direction (not back and forth), and lift the magnet away from the needle for the return trip. After about ten strokes, test the needle. You will find it can pick up iron filings and other light pieces of metal. It is magnetized.



Tie a length of fine sewing thread to the middle of the bar magnet, and suspend the magnet so that it hangs freely (be sure to stand away from large metal objects). The magnet will slowly align itself with the earth's magnetic field until one end is pointing to the north. That end is the north-seeking pole, generally called the north pole. Mark it with an N. Do the same with the magnetized needle, noting whether the north-seeking end is the eye or the point.

Now, with the magnetized needle suspended, advance the N pole of the bar magnet toward it. Notice the N end of the needle swing away from the N end of the magnet and the S end of the needle move toward the magnet. This action demonstrates the law of magnetic force: Opposite poles attract, and like poles repel.

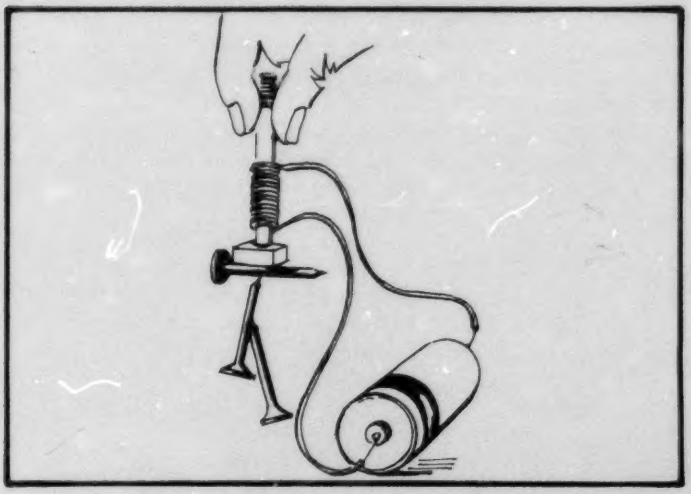
The reason a freely suspended magnet points its north-seeking pole toward the earth's arctic region is that the earth itself is a giant magnet with its magnetic N pole near the geographic North Pole. Thanks to this happy circumstance, the compass exists.

EXPERIMENT 7

Making an Electromagnet

THINGS YOU NEED. Iron bolt or spike. A few feet of hook-up wire. Flashlight battery. Various small metal objects.

Wind about 20 turns of wire around the bolt, then connect the ends of this coil to a battery. The bolt is now an electromagnet and will attract metal objects as surely as your permanent bar magnet. But when the battery is disconnected, the bolt will lose its magnetic force.



The strength of an electromagnet is determined in part by the number of turns of wire it has. The more turns of wire you put on, the stronger the electromagnet gets, within limits. With the right amount of turns, our small electromagnet will probably be able to pick up a hammer. Electromagnets can be made quite strong. For this reason they are used in scrap yards to lift large piles of metal.

EXPERIMENT 8

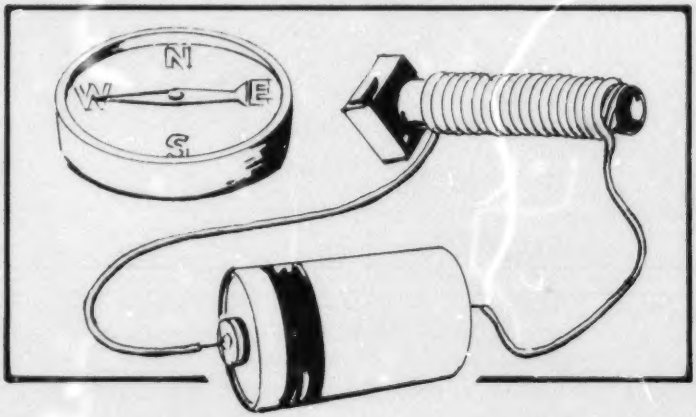
Magnetism and the Compass

THINGS YOU NEED. Electromagnet from Experiment 7. Compass.

Place the compass on a flat surface with the needle pointing to N. Connect the electromagnet, and bring it near the compass. Note which way the needle deflects.

Now without moving the electromagnet, reverse the battery connections. The needle should deflect in the opposite direction.

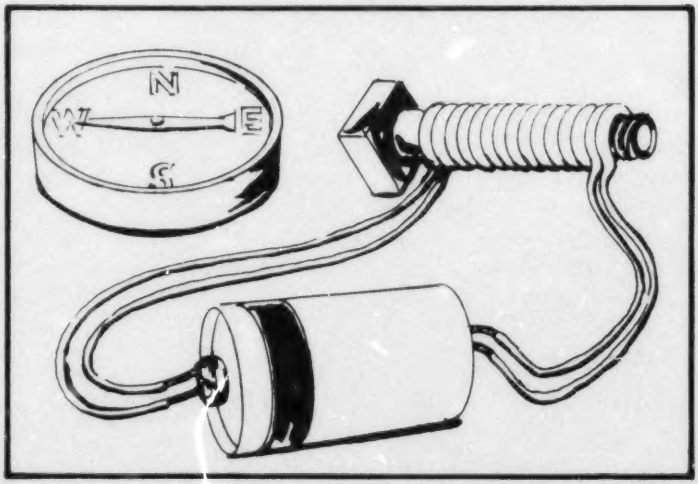
You have just repeated the historic discovery of a Danish schoolteacher named Hans Christian Oersted. He concluded that since current in a wire deflected a compass, it must be producing magnetism. It was one of the most important discoveries of all time. The motor operates on this law of nature.



EXPERIMENT 9
An Electromagnet with Two Coils

THINGS YOU NEED. Same as in Experiment 8, plus more wire.

Wind another coil of wire around the bolt. Put on the same number of turns as before. Then connect the ends of the second coil to the same battery. With both coils energized, note what the compass does. Now reverse the connections on the second coil, and again check the compass.



Here's what happened. When the current in both coils traveled in the same direction, the compass needle deflected as it did with only one coil. When the current in the coils traveled in opposite directions, the compass needle did not move at all, or just slightly. That's because the magnetic fields set up by the coils were now aligned differently, and the fields opposed or balanced one another. This experiment demonstrates that you can control the magnetism of the bolt by reversing connections on either coil.

Through experiments like these, Edison found several methods of varying the magnetism in telegraph systems: change the direction of current flow through coils, change the amount of flow, change the direction in which coils were wound. He combined these methods over the same wire. That was the duplex.

He then arranged to have two messages sent from the home station to a distant station while, at the same time and on the same wire, two messages were coming in from the distant station . . . four messages simultaneously. That was the quadruplex.

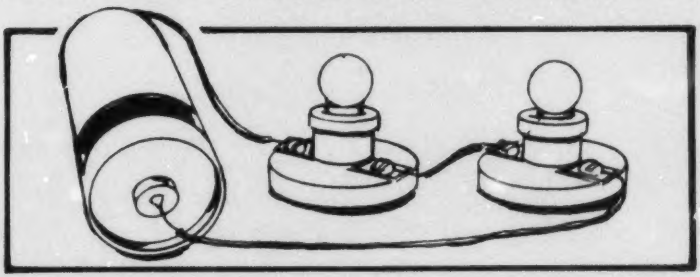
EDISON'S HOME LIGHTING CIRCUIT

While Thomas Edison was trying to invent the incandescent electric light in 1879, he was also working on a system that would enable this light to be used in the home. That system included central power generators, switches, insulating materials, meters, and many more items.

An important part of this system was a parallel wiring circuit for homes. Up to that time, the only electric lights in existence were the extremely brilliant carbon arc lamps that were beginning to be used for street lighting. These had to be connected in series. The following experiment shows the difference between the two types of circuits.

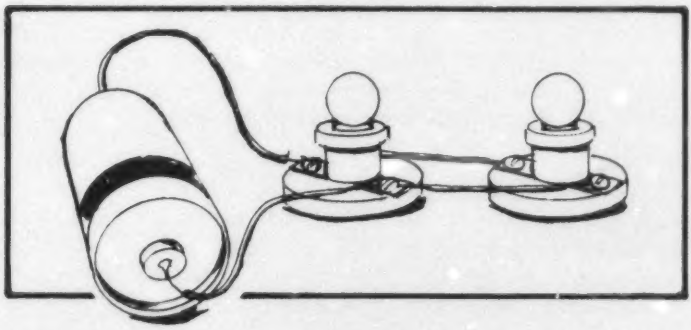
EXPERIMENT 10
Series and Parallel Circuits

THINGS YOU NEED. 2 or 3' of hook-up wire. 2 flashlight bulbs and sockets. Flashlight battery.



Start by setting up a series circuit, as shown. When final connections have been made and the bulbs are lit loosen either bulb. Note that no matter which one you loosen, when it goes out so does the other.

This is one reason Edison considered the series circuit impractical for his grand plan. Imagine having to light up an entire house just to read the newspaper, or having the entire house go dark because one bulb burned out.



Now change to a parallel circuit. Screwing either bulb out of its socket does nothing to the other bulb. The other bulb will continue to burn. You can thus see, as Edison did, the advantage of a parallel circuit for home use. It allows individual lamps to be turned "on" or "off" without affecting other lamps in the circuit.

EXPERIMENT 11

The Fuse in Action

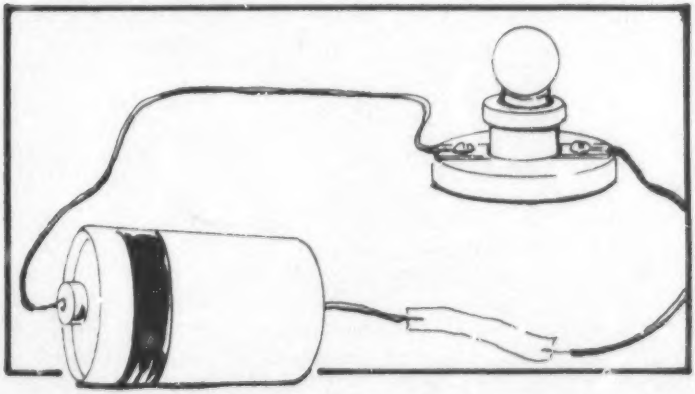
THINGS YOU NEED. Wire, bulb, socket, and flashlight battery from Experiment 10 (you may need 2 batteries). A strip of Christmas tree tinsel (silver icicle).

Undoubtedly the smallest, though not the least important, device in Edison's home lighting system was the fuse. Something like an automatic safety switch, the fuse cuts off the current when it becomes high enough to cause a fire. Danger-

ously high currents in the main lines are the result of too many branch circuits being used at the same time (overloading the lines). Or they are the result of the "live" wire accidentally touching the "ground" wire or anything else that is grounded, such as a water pipe. This accidental touching is known as a "short circuit."

Edison's first fuse was patented on March 10, 1880, under the name "Safety Conductor for Electric-Lights." He intended that such a fuse be placed in the circuit of each lamp or other electrical device.

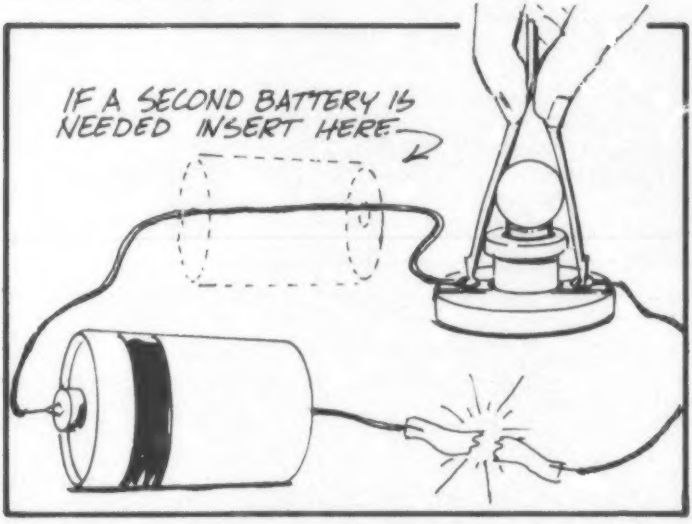
It consisted of a piece of thin, special wire enclosed in a tube made of a non-conducting material. The wire had a low melting point. Whenever a short circuit (high surge of current) developed, the heat of the high current would melt the wire immediately — opening the circuit before any great damage occurred. The tube served to keep the droplets of molten metal safely contained and to prevent the two ends of the conductor from separating.



You can easily demonstrate how the fuse works. Lay two small lengths of wire on a flat surface so that the wires are in a straight line and 1" or less apart. We're going to connect a piece of tinsel across the 1" gap. Use tape to make your connections, and be sure there is good contact at both ends of the tinsel. This will be our fuse.

Now comes the test. Connect the fuse wires with the lamp and flashlight battery, as shown. Use tape to hold the wires to the battery ends. If everything is in order, the lamp will light.

To see the fuse in action, we'll have to produce a short circuit. Do this by touching the two terminals of the lamp socket at the same time with a pair of tweezers or another piece of wire. That will allow the current to bypass the lamp, taking a short cut, you might say.



Without the lamp to act as a resistance, the current becomes much higher than it was. The load will probably be more than the tinsel can carry. If so, the tinsel will overheat, melt, and open the circuit. However, you may have to use two batteries in series, depending on the thickness of the tinsel. If it weren't for our homemade fuse, the power source would spend itself in seconds.

We get this same kind of protection from our home fuses (and circuit breakers). Edison foresaw the possible dangers of electrical overloads and short circuits. That's why he felt the fuse was a necessary part of his system.

FARADAY EXPERIMENTS

More than anything else, Thomas Edison loved to experiment. And he was unexcelled at it. Nikola Tesla, a European-born American inventor, wrote that if Edison wanted to find a needle in a haystack, he would examine straw after straw with the feverish diligence of a bee until he found the object of his search.

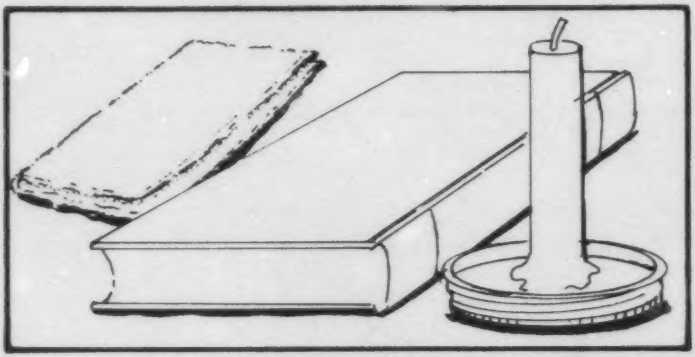
This intense interest in learning things for himself began at the age of nine when his mother gave him a book on simple experiments. Edison read and performed each experiment in the book with the methodical thoroughness for which he was to become renown.

Years later, he bought two books on electrical experiments written by Michael Faraday, the great English scientist. Faraday made a lasting impression on Edison. In fact, Edison regarded the buying of Faraday's books as one of the decisive events of his life. "It was in Boston I bought Faraday's works," Edison recalled. "I think I must have tried about everything in those books. His explanations were simple. He used no mathematics. He was the master experimenter."

The following experiments are based on the research done by Faraday. Perhaps you will receive the same scientific inspiration in doing them as Edison no doubt did when he duplicated Faraday's experiments over 100 years ago.

One of Faraday's most popular experiments is generally known as the "ice pail" experiment. It represents the first proof that electric charges cannot be stored within a hollow conductor (Faraday used an ice pail) because they invariably travel to the outside surface.

To perform this experiment you will first have to build an electrophorous (eh-lek-TROF-or-us) and an electroscope.



EXPERIMENT 12
Building an Electrophorous

THINGS YOU NEED. A book. Sheet of polyethylene (from a dry cleaning or vegetable bag). Piece of fur or wool. Bare metal disk (cover from a mayonnaise jar). Insulating rod (candle, glass, dry wood). Sandpaper.

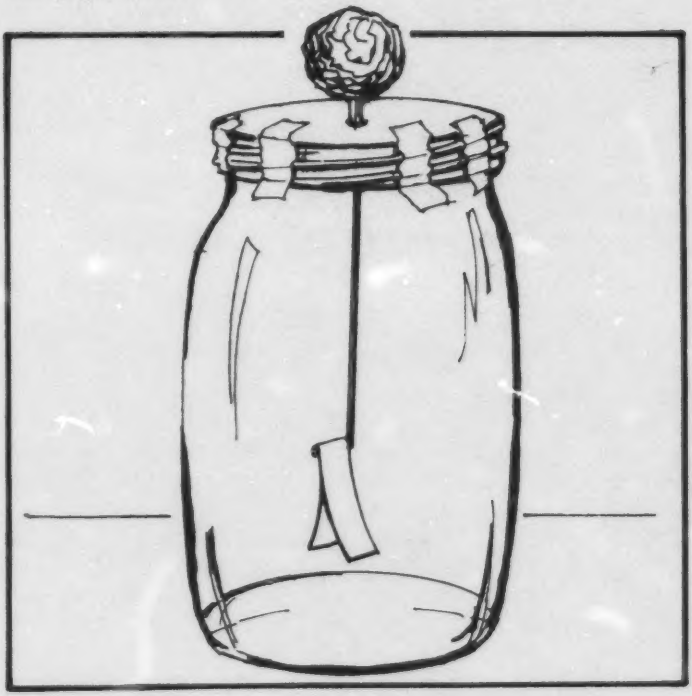
The electrophorous is an electrostatic generator invented by Alessandro Volta in 1775. It consists of two parts: a charging plate and a charge-transfer disk. The simplest way of making the charging plate is to wrap a sheet of polyethylene around a hard-cover book, keeping the top fairly smooth and tucking the edges under the bottom. You may want to build something more permanent, in which case your own resourcefulness is your best guide.

To make the charge-transfer disk, sand the top of the jar lid down to bare metal. Drop some melted wax from a candle on the inside of the lid (if it has a waxed cardboard liner that is dry, leave it in; it will reduce the chance of charge leakage) and set the candle base on the wax before it hardens. If you don't have a candle, glue a glass rod or some other insulating handle to the lid. You now own an electrophorous. We'll discuss how it works in a moment.

EXPERIMENT 13
Building an Electroscope

THINGS YOU NEED: Wide-mouth jar or drinking glass. Thin cardboard to cover jar opening. A 6" length of stiff bare wire. Silver foil from a chewing gum or chocolate bar wrapper. Sheet of aluminum wrapping foil about 12" square. Tape.

The electroscope is a sensitive instrument for indicating the presence of an electrical charge. To build one, start by soaking the silver foil wrapper in warm water to separate the foil from the paper liner.



While this is going on, cut the cardboard into a disk slightly wider than the jar opening. Use a large needle to pierce a hole in the center of the cardboard for the wire to pass through snugly. Next, squeeze the aluminum sheet into a ball. Then make an L-shaped hook in the wire about 1/2" from one end, insert the other end through the cover, and jam it into the aluminum ball.

Now back to the silver foil wrapper. Peel the foil from the liner, dry it, and smooth it out. Cut a strip 3" long and 1/4" wide. Fold the strip in half and place it over the hook. Be sure the ends hang side by side. If they don't, press them together gently.

Finally, lower the entire assembly into the jar, and tape the cover in place. If the wire slides down into the jar, a few turns of tape around the wire will keep things in place. That takes care of the electroscope.

EXPERIMENT 14

Faraday's "Ice Pail" Experiment

THINGS YOU NEED. Your electrophorous. Your electroscope. A metal container such as a large coffee can.

Before conducting this experiment, you should test the equipment you just built. Do it as follows: Charge the electrophorous by rubbing the charging plate vigorously with the fur or wool. Then set the charge-transfer disk on the surface, and touch the disk with your finger. This is an important step because your finger removes electrons and allows the disk to become positively charged. If you lift it up holding only the candle, the disk will stay charged until you discharge it. Try bringing it close to your finger; you will draw a small, harmless spark and hear a snap.

After recharging the disk, bring it near the foil knob atop the electroscope, but don't touch the knob. The foil leaves should spread apart. As you move the disk away from the knob, the leaves should slowly drop. The angle that the leaves make in the presence of a charge indicates the strength of that charge. The greater the angle, the stronger the charge. If the disk should happen to touch the knob, the leaves will remain apart after the disk is withdrawn. In that event, simply touching the knob will discharge the electroscope.

Now for Faraday's "ice pail" experiment. As indicated earlier, Faraday devised this experiment to prove that electrical charges prefer the outside of a hollow conductor to the inside. You can prove it too.

Insulate the "ice pail" container by setting it on glass (use a framed picture). Hang a small strip of silver foil, about 3" by 1/2", on the outside of the can near the top. Attach it with tape. Now with your electrophorous, induce a charge in the charge-transfer disk (remember to touch it with your finger before removing it from the charging plate), and lower the charged disk into the can, without touching the sides. A charge will be

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induced on the inside of the can, but it will transfer immediately to the outside as indicated by the hanging foil, which will move outward slightly. You may have to look closely to perceive any movement of the foil.

Touch the disk to the inside of the can. This will discharge the disk. You may even see a spark jump. Make sure that the disk is discharged by bringing it close to the electroscope knob. The leaves should not react. Now to verify that charges do indeed prefer the outside surface of a conductor, lay the uncharged disk against the outside of the can to pick up any charges (don't forget the finger trick). Then bring it near the electroscope again. The leaves should now diverge, proving the point.

For further proof, set the electroscope inside the can. Charge the outside of the can with the charged disk of your electrophorous. Although the foil strip on the can will move, indicating a charge is present on the surface, the electroscope will show the interior to be neutral. Faraday's ice pail experiment explains why it is safe to sit inside a closed car during a thunderstorm.

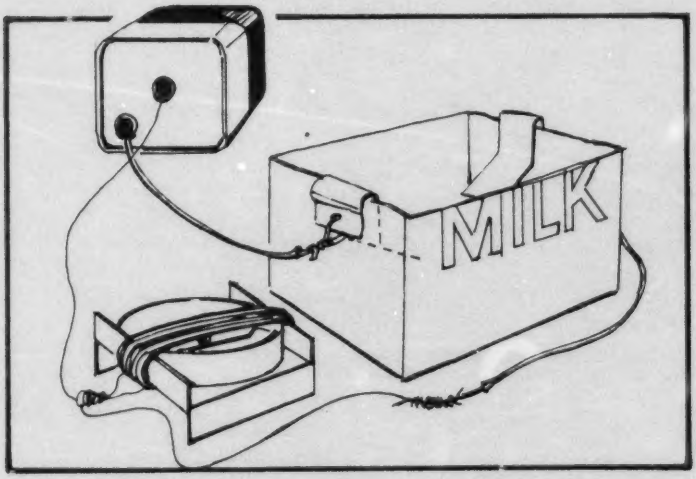
EXPERIMENT 15

Does Ice Conduct Electricity?

THINGS YOU NEED: 2' of hook-up wire. 2 strips of copper, 1" by 3". Waxed paper or plastic container. 6-volt (or flashlight) battery. Galvanometer from Experiment 1.

Michael Faraday was deeply interested in electrical conductivity. And he measured the flow of electricity through many substances. One of these was ice. Concerning his experiments with this material, Faraday said, "I was working with ice when I was suddenly surprised to find that ice was a nonconductor of electricity."

This fact would probably surprise most people, since water is known to be a conductor (except when pure). But let's find out about ice for ourselves.



To the end of each copper strip, solder a foot of wire, bared at the ends. If you have no soldering equipment, punch a hole in the copper, loop the wire through, and twist it tightly. Bend back the tops of the copper so you can hook the strips on opposite sides of your container. Then angle the hanging part of the strips inward until the ends come within an inch or so of each other.

Form a series circuit by connecting one copper strip to the galvanometer, the other end of the galvanometer to either battery terminal, and the remaining battery terminal to the second copper strip. The only thing missing to complete the circuit is a conducting medium to electrically bridge the copper strips.

With ordinary drinking water, fill the container to about 1" from the top; at the same time, keep an eye on the galvanometer. You may or may not get a response, depending upon what part of the country you live in. If the water in your area is

hard; that is, if it has a high mineral content, it will pass current, as the galvanometer will show. But if the water in your area is soft, there's a chance it won't conduct enough current in this particular experiment to deflect the compass needle (it can still conduct dangerous quantities in other circumstances, though, so don't be misled).

If the needle on the galvanometer did move, showing that your local water conducts electricity, the next step is to place the container (with copper strips still attached) in a freezer, or outdoors if it's cold enough. If your galvanometer needle did not move, you'll have to add enough salt to the water till it does. Then likewise freeze the container.

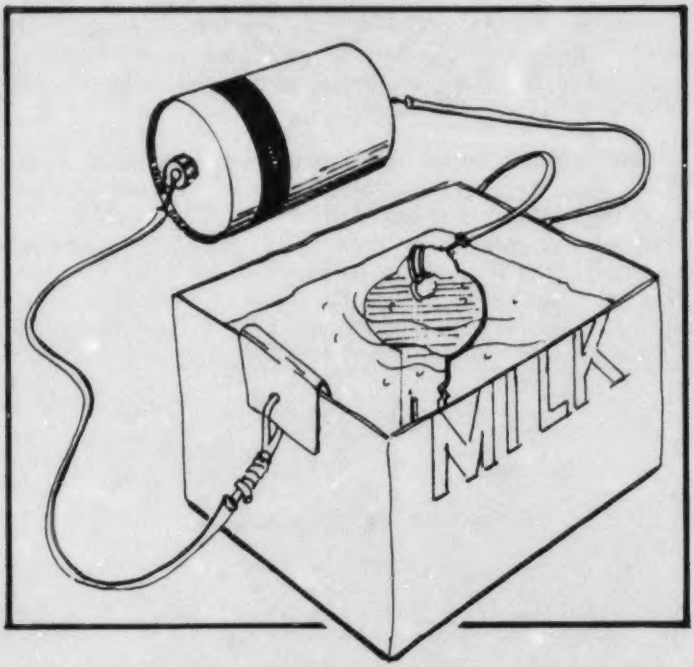
When the water has frozen solid, re-install the container and copper strips in the original circuit. You won't get a reading on the galvanometer, because, as Faraday observed, ice is a very poor conductor. Not until a big enough path has been established through the partially melted ice will sufficient current flow to begin moving the compass needle. And as the path becomes bigger, the needle will increasingly deflect until it reaches a maximum.

EXPERIMENT 16

Electroplating Your House Key

THINGS YOU NEED. Copper strip and container from Experiment 15. Salt and vinegar. 2' of hook-up wire. Key or other metal object (plating will not affect its useability). Flashlight battery (a fresh one).

In addition to his findings about electrical charges and conductivity, Michael Faraday made many other contributions to science. Certainly among the more important were his discoveries in the field of electroplating.



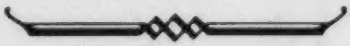
Electroplating is a process in which one metal is gradually deposited on another metal by means of electricity. Here is a simple experiment that shows the action involved.

Pour vinegar into the container until it is about half full. Add a tablespoon of salt, and stir. If all dissolves, keep adding salt and stirring until the vinegar will dissolve no more (at which point the salt will begin settling to the bottom). This gives us the saturated solution we need.

Take 1' of the wire and solder one end to the copper strip and the other end to the button on top the flashlight battery. If you don't have a soldering gun or iron, tape will also work. Similarly, connect the bottom of the battery to the key, or whatever else you decide to copper plate, using the other 1' of wire. Just looping the wire through the key hole and twisting it will be sufficient. The key must be clean and dry.

Now immerse the copper strip and key into the vinegar-salt solution, making sure the two pieces of metal do not touch each other. Soon you will notice bubbles forming on the key and the color of the solution changing.

What is actually happening is that copper is being dissolved off the strip, driven across the solution by the current, and being deposited on the key. At the same time, hydrogen is being released from the water in the vinegar and bubbling on the key. These bubbles must be wiped off periodically or the electroplating action will slow down. After a while you should be able to see a thin coating of copper form. Eventually you will have a nice, shiny copper-colored key.



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